## REACHING FOR THE MOON: THE FUTURE OF SPACE EXPLORATION

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I am going to talk this evening about our nation's space exploration program and where it is going in the decade of the sixties. But first I want to say a few words about the agency for which I work, the National Aeronautics and Space Administration, or NASA for short.

NASA is just a little over two years old, having come into existence on October 1, 1958. It is a civilian agency totally outside the Department of Defense. It is headed by a civilian administrator who answers directly to the President.

The law which established NASA, the National Aeronautics and Space Act of 1958, did two unprecedented things. First, it announced to the world that it is the policy of the United States that activities in space shall be devoted to peaceful purposes for the benefit of all mankind. The reasons for establishing a new

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civilian agency for space activities were closely tied in with this declaration of national policy.

In the second place, the 1958 Act created an entirely new mission of government, the exploration of space. The Act specifically directs NASA to conduct such activities "as may be required for the exploration of space."

This is a mission which is unique to NASA among the agencies of government. The armed services and the Department of Defense have no comparable mission in space. The 1958 Act recognized the responsibility of the military to conduct space activities "peculiar to or primarily associated with the development of weapons systems, military operations, or the defense of the United States," but this does not embrace the exploration of space for its own sake. Thus, when we speak of the nation's space exploration program, I think it is important to know that we are not speaking of the military uses of space. On the military side, it is hardly appropriate to speak of a "space program." In fact, it is no more appropriate than to speak of a land program, a sea program, or an air program in the military context. The military utilization of space and the research and development effort directed toward that end are integral parts of the total defense program of the United States. Each of the armed services -- Army, Navy, and Air Force -- have a share in this program and, accordingly, a certain responsibility for the best utilization of space for the defense of the nation. But no one of them is required to conduct any portion of its military mission in space simply because space is now, for the first time, accessible to man. Military space projects must always compete in the total military budget with alternative means of accomplishing the same military objectives, and they will be undertaken only if they survive this competition.

NASA, on the other hand, has been directed by statute to conduct the new governmental mission of space exploration. This is a mission which the Congress, for obvious reasons of public policy, has decided must be performed for its own sake without having to justify it in relation to the defense needs of the nation or, for that matter, to the economic benefits which may possibly flow from it. It is a mission which stands firmly on its own two feet, justified by nothing more specific or tangible than the total national interest in maintaining leadership in science and technology and in their application to the conduct of peaceful activities for the benefit of all mankind. This, then, is the mission of NASA.

Now what does this broad mission to explore space comprehend? First of all, it includes using the new tools of the space age to conduct scientific experiments in space and thereby expand man's knowledge of his environment. It also embraces the development of practical applications of space systems to benefit our everyday life. But it doesn't stop there. Ultimately, and essentially, it means the sending of man himself into space.

Now I am not going to recount the details of what our Government has been doing in space since NASA was established, since I am sure that you are more interested in hearing about where we are going than where we have been. Each of our failures -- and there have been several -- and each of our successes -- and there have been quite a number of these -- have been duly headlined by the press around the world. It is evident to all, I think, that the pace of the program has been quickening in recent months and that successes are becoming more frequent and notable than failures. I shall simply summarize progress to date by noting what we like to call the "box score." Up to the present time, the United States has launched a total of 26 earth satellites, of which 15 are still in orbit. The Soviet Union has launched six and, of that number, one is still up. In addition, the Soviet Union has one satellite orbiting the sun, while the United States has two, Pioneers IV and V. The Soviet Union also has one lunar impact to its credit. The United States has recovered two satellites from orbit, and the Soviet Union has recovered one. So I think we can all agree that the box score looks pretty good. In addition, it is fair to say that the volume of useful scientific information which has been published as a result of United States launchings to date substantially exceeds the Soviet output.

As all of you know, the past six months have been a period of particularly intense activity on the part of the United States in exploring space. I will mention three of our projects as examples of the richness and diversity which characterize our nation's space exploration program. Last March, Pioneer V was launched successfully into an orbit about the sun between earth and Venus. Weighing only 95 pounds, it contained 40 pounds of useful instruments designed to investigate interplanetary space and to test extreme long-range communications. The project was highly successful, transmitting data back to earth for a period of 106 days. When communication finally ceased, Pioneer V was 22.5 million miles from earth, and it had transmitted 139 hours of data. This distance was 50 times farther into space than man had previously communicated. Incidentally, our scientists estimate that Pioneer V will continue in orbit about the sun for at least 100,000 years, during which time its distance from the sun will vary from 73 million to 92 million miles. Not only are we disproving the old saw that "everything that goes up must come down," but we are also achieving what is virtually perpetual motion.

The next project to make history was TIROS I, launched last April. With this satellite we have taken the first steps on the road to a revolution in weather forecasting. During its active life of three months, while it circled the earth at a height of 450 miles, it took more than 22,000 remarkably fine photographs of the earth and its cloud cover. A few weeks ago NASA announced that, jointly with the Weather Bureau, it had issued an invitation to foreign governments to participate in meteorological research connected with the next and more advanced TIROS satellite, which is due to be launched later this year.

And finally, I will merely mention Project Echo in passing, since I am sure it is well known to all of you. While Echo has made a spectacular show in the sky which has dramatized this new technology as nothing else has, we should not lose sight of the fact that it has had a very practical purpose to serve. With it we have made communications history, as it has successfully demonstrated that a passive satellite can be used to relay voice and continuous-wave signals, first across the continent and then across the Atlantic. Photographs have also been transmitted successfully by this means.

In addition to these three that I have mentioned, Pioneer V, TIROS I, and Echo, the Air Force has been conducting a highly successful series of launchings and recoveries in recent months in its Discoverer program, culminating last August 19 when a reentry capsule weighing 300 pounds was ejected from the satellite and snatched

8,000 feet in mid-air by an Air Force plane, about 360 miles southwest of Honolulu.

Also, the Navy has had fine success in recent months with its TRANSIT navigational satellites, which promise to provide us with better and more continuously reliable methods of navigation.

And, most recently, the Army's Courier satellite was a successful demonstration of an active communications satellite operating on the delayed repeater principle. It is capable, in a single pass, of receiving, storing, and later transmitting on command up to 375,000 words.

With all of this successful activity going on, why do we still hear talk about the alleged superiority of the Soviet Union in space? Before attempting to answer this question, we shall have to take a look at one of the major elements of space technology.

First of all, before we can think seriously about doing anything in space we must have the means of propelling a useful object, a spacecraft such as the Echo satellite, from the earth into outer space. The propulsion and guidance systems necessary to put a spacecraft into orbit about the earth or into a flight path toward the moon are combined in what we call launch vehicles.

You are all acquainted with pictures of the Atlas ICBM and the Thor and Jupiter IRBM's. These are launch vehicles designed originally not for space exploration purposes but to launch nuclear weapons thousands of miles toward an enemy target. Up to the present time, the launch vehicles which we have used in our space exploration program have largely employed rockets developed for use in these ballistic missiles, the intermediate-range Thor and Jupiter and the intercontinental-range Atlas. The Russians likewise have been able to use rockets developed for their long-range ballistic missile weapons. Theirs are presently considerably more powerful than ours, and there is a simple historical reason for this, having nothing whatsoever to do with space exploration as such. I feel it is so important that this be understood that it is worthwhile for us to spend a few minutes reviewing a bit of recent history.

In the late 1940's, the United States chose to continue its reliance on the heavy bomber as the delivery system for nuclear weapons. At that time the Soviet Union decided on a very different course. Instead of emphasizing the heavy bomber as we did, they chose to develop ballistic missiles as the means for delivering nuclear weapons over intercontinental distances. We did not make a similar decision until 1954. Thus, they gained a head start of several years in the research and development work that ultimately led to the big rockets now being used by the Soviet Union for both missile weaponry and space exploration. Furthermore, they began development at a time when the Russian nuclear warheads were very large, heavy, and relatively inefficient, and so they were compelled to develop a more powerful launch vehicle than was later selected by us. The early versions of our atomic bombs were heavy and large also, but we concentrated at that time -- the late 1940's and early 50's -- on the manned bombers as the means for delivering our nuclear warheads. Only after we had solved the problems of producing lighter, smaller, and enormously more efficient atomic and hydrogen bombs did we start an all-out program to produce a rocket-propelled launch vehicle to carry these bombs to the target. Thus, our decision to develop intercontinental ballistic missile systems was made only after nuclear warhead development had proceeded to the point where we could plan on smaller vehicles to deliver the punch. I might add that, in a little more than half the time taken by the Russians, our scientists, engineers, and industrial contractors have produced the Thor and Jupiter IRBM's and the Atlas ICBM as operationally useful missiles capable of carrying to the target, with the required accuracy, warheads as powerful as our defense needs require. Let me emphasize that the difference in thrust between our rockets and the Soviet rockets in no way means that our ballistic missile weaponry is inferior to theirs. As a matter of fact, it is probable that the rockets which the Soviets today possess are more powerful than they now need for military weapons purposes.

The story is different when we turn from weapons to space exploration. While our rockets, used in our military missiles, can carry a warhead to the desired target with accuracy in the same manner as the Soviet rockets presumably can, their more powerful rockets, when employed in launch vehicles for space exploration purposes, have enabled them to perform some feats in space which we are not able to match. The reason is simply that the Russians, with their higher-thrust propulsion systems derived from their ballistic missile program, can project into outer space heavier spacecraft than can the United States. Heavier spacecraft mean, of course, a greater variety of scientific instruments, more animals, and even more men.

Up to the present time, we have had to rely almost entirely upon the rockets employed in the Thor and Jupiter IRBM's, having about 150,000 pounds of thrust, to provide propulsion for the first stages of our launch vehicles. In only a few cases to date has the United States been able to use the Atlas ICBM rocket, having 360,000 pounds of thrust, for space exploration missions. By contrast, the Soviet scientists have had at their command a first stage which we estimate is in the 600,000 - 800,000-pound-thrust range.

With their more powerful launch vehicles, the Russians have been able to place in orbit spacecraft weighing as much as 10,000 pounds. This was the size, for example, of the satellite which was launched on August 19, containing a variety of animals, insects, and plants and which, according to Soviet reports, was successfully recovered by landing within the Soviet Union. With our present launch vehicle systems, we cannot equal the size of the spacecraft which the Soviet Union is able to launch into outer space.

Space technology, of course, is a very complex thing involving innumerable elements other than rocket propulsion. I think it is safe to say that, in every other aspect of space technology, the United States is at least equal with, and in some cases ahead of, the Soviet Union. But this matter of the weight-lifting capability of our launch vehicles is a real limiting factor at the present time. And the development of a new launch vehicle can't be accomplished overnight -- it takes several years.

Government and industry are working together to remedy this deficiency as rapidly as possible. Both NASA and the Department of Defense are urgently engaged in developing a family of launch vehicle systems that will greatly increase our capabilities to undertake major missions in space. These new launch vehicles are the Thor-Agena B, the Atlas-Agena B, the Centaur, and the Saturn. The first two are being developed by the Air Force; while Centaur and Saturn are NASA's development responsibilities.

In comparing the expected performance of these new launch vehicles, it is necessary to use a common yardstick. This yardstick is the number of pounds of payload each will be capable of placing in orbit at an altitude of 300 nautical miles. An alternative yardstick is the number of pounds of payload which it can send on what is called an "escape trajectory" beyond the earth's gravitational field into a deep space mission, such as toward the moon or one of the planets.

As a basis for comparison, we might note that the Delta launch vehicle, which was used to place the Echo satellite in orbit and which will be used to launch a number of satellites during the coming months, is rated as being capable of placing a 480-pound payload in a 300-nautical-mile orbit, and a 65-pound payload on an escape trajectory. We can do many useful things with this launch vehicle, but it clearly doesn't put us in a position comparable to that of the Soviet Union.

Our capabilities will increase substantially with the Atlas-Agena B. This launch vehicle, now under development, will use the Atlas ICBM as the first stage and a second stage known as Agena B. This second stage is an enlarged version of the one that has been used very successfully in the launch vehicles used in the Air Force's Discoverer program. It will be available to NASA in the third quarter of 1961, according to present plans. With this launch vehicle, we will be able to place a 5,000-pound payload in a 300-nautical-mile orbit and send a payload of 750 pounds on an escape trajectory.

By combining the Agena B second stage with the Thor IRBM, a launch vehicle known as Thor Agena B will be developed next year and made available to NASA early in 1962. While not as powerful as Atlas Agena B, it will greatly exceed our present capabilities and provide us with greater versatility in our space program. Thor Agena B will be able to place a 1,600-pound payload in a 300-nautical-mile orbit.

Neither of these, however, will match the present Soviet capability in the launch vehicle field. The first launch vehicle to accomplish this will be Centaur, now under development and slated to begin flight testing about the middle of next year. Centaur uses the Atlas ICBM as the first stage and a new second stage utilizing liquid hydrogen as fuel. Centaur will be capable of placing an 8,500-pound payload in a 300-nautical-mile orbit, and 1,450 pounds on an escape trajectory. It should be available for its first operational mission early in 1962.

As the result of this development program, within the next 12 to 18 months we should have available launch vehicles that will enable us to launch spacecraft equalling in size anything the Soviet Union has done to date. We cannot, of course, assume that they will not progress in the meantime. So our goal cannot be merely to catch up. Consequently, our highest priority in the launch vehicle field is Saturn, a vehicle designed to have a capacity of an entirely different order of magnitude from anything that has been demonstrated to date by the Soviet Union.

In its initial configuration, which we call Saturn C-1, Saturn will be a three-stage vehicle. The first stage consists of eight engines of the type used in the Thor and Jupiter IRBM's, clustered to produce 1,500,000 pounds of thrust, or roughly four times the thrust of the Atlas ICBM. The second stage utilizes four Centaur engines using liquid hydrogen and liquid oxygen as propellants and producing a thrust of 70,000 pounds. The third stage will be the same as the second stage of the Centaur vehicle, which I have previously described, producing 35,000 pounds of thrust.

The first stage will be ready for testing next year, and the second and third stages in 1963. Saturn C-1 should be ready for its first operational mission some time in 1964.

It is designed to be able to place a 19,000-pound payload -- almost 10 tons -- in a 300-nautical-mile orbit. It should also be capable of sending a 6,000-pound payload on an escape trajectory.

A later configuration of Saturn, called C-2, is also under development. This will involve a new second stage consisting of four very powerful engines fueled by liquid hydrogen and liquid oxygen, with a total thrust of 800,000 pounds.

By fiscal year 1967, we expect that our present launch vehicle development program will give the United States the capability of launching spacecraft weighing as much as 50,000 pounds.

Looking beyond Saturn, we have under development by North American Aviation the F-1 engine, designed to produce 1.5 million pounds of thrust in a single chamber, roughly the equivalent of the entire thrust of the first stage of Saturn and about four times that of the present Atlas. It will not be available for use until some time after 1965. These tremendous engines may be clustered in a launch vehicle to produce a total thrust of up to 12,000,000 pounds in the takeoff stage, conceivably as much as 30 times that of Atlas. We have used the term "NOVA" to refer to the concept of a launch vehicle employing such a propulsion system, but the configuration of such a vehicle has not yet been determined.

I should not leave the subject of launch vehicles without saying a word about the prospects for nuclear propulsion. All of our existing launch vehicles, plus Centaur, Saturn, and the F-1 engine to which I have just referred, employ chemical means of propulsion; that is, they rely for their thrust upon the energy generated by the chemical inter-action of liquid oxygen and a liquid hydrocarbon fuel, as in our present launch vehicles, or liquid hydrogen, as in Centaur and the upper stages of Saturn.

For very long-distance missions involving large payloads, these systems are not competitive with nuclear propulsion. For example, let us imagine a mission designed to orbit Mars. It may begin by placing a spacecraft weighing 150,000 pounds into orbit about the earth. This can be accomplished by chemical propulsion. The next step is to propel it out of its earth orbit onto a trajectory toward Mars, and finally to return it again to an earth orbit. If we employ chemical propulsion for this purpose, we can probably send only a 3,000-pound payload on such a mission (assuming an initial spacecraft weighing 150,000 pounds). But if we employ nuclear propulsion, the size of the useful payload on the trip to Mars will be increased seven to ten times. Thus, for such long-range missions, nuclear propulsion will probably be the leading contender in coming years.

The research and development work on space nuclear systems is being conducted jointly by NASA and the Atomic Energy Commission. The first flight test of a nuclear rocket designed for use as a top stage in high-thrust vehicles will probably occur in 1965; but it is still too early to describe the specific mission for which such an engine will be employed.

Now you might ask what NASA intends to do with this array of powerful launch vehicles during the decade of the sixties. Early this year, NASA announced a 10-year program of space exploration which may be regarded as having three main subdivisions: first, our space science program, which is designed to increase our basic scientific knowledge about space; second, our program for developing useful applications of satellites to improve our day-to-day pattern of living; and finally, the exploration of space by man himself.

## Space Science

In the first of these areas, the space science program, we have three comprehensive objectives: (1) to investigate solar-terrestrial relations, the relationship of the sun and the earth; (2) to probe the fundamental workings of the solar system and the universe; and (3) to search for other manifestations and forms of life within our solar system.

During the next few years, we plan to place in orbit a number of very complex satellites which are known by such impressive names as "Orbiting Solar Observatory," "Orbiting Geophysical Observatory," and "Orbiting Astronomical Observatory."

In addition, the program includes lunar and planetary missions with unmanned vehicles. This will begin with flights designed to send an unmanned spacecraft into orbit about the moon and to transmit its observations back to earth. It will be followed in 1962 by "Project Ranger," consisting of a series of launchings by Atlas-Agena vehicles of spacecraft designed to impact the moon. This spacecraft, presently under development, is being designed to carry a capsule which will survive the shock of impact and will contain a seismograph as the primary experiment. It will also be equipped with high resolution television cameras which will transmit a picture of the moon's surface during the approach to landing.

Project Ranger will be followed by an extensive series of missions designed to make soft landings of instruments on the moon. This project we call "Surveyor." It will utilize the Centaur launch vehicle to deposit on the moon's surface a scientific payload weighing as much as 300 pounds, which will examine the surface and subsurface characteristics of the moon, the lunar atmosphere, magnetic fields, etc., with a veriety of instruments, including television. We hope to begin actual development of such a spacecraft early in 1961.

The next step will be to send a spacecraft to the moon which will be able to deposit a mobile laboratory on the surface. This we call "Prospector." It should be capable of exploring the moon's surface throughout a radius of perhaps 50 miles, terrain permitting, and thus obtain vastly more useful data than could be obtained with stationary craft. Such a spacecraft requires Saturn as the launch vehicle, which means, of course, that it cannot be planned for flight before the mid 1960's.

I should not leave the space sciences field without mentioning the planetary program briefly. When Centaur becomes available in 1962, it will be possible to launch spacecraft to fly close to the planets Mars and Venus to obtain scientific observations not only of those planets but of the interplanetary environment en route. In the second half of the 1960's, we hope to have Saturn available for this program of planetary exploration. It is planned to use Saturn to launch a spacecraft, which we call Voyager, to orbit Mars and Venus. It would be designed to eject an instrumented capsule for entry into the planet's atmosphere and perhaps land on the planet itself.

Data transmitted by the capsule could be stored and relayed by the mother craft in orbit about the planet or perhaps even be received directly on earth.

All of this exploration with unmanned spacecraft, of course, is an indispensable prerequisite to manned space exploration.

Practical Applications

So much has been said in recent months in connection with TIROS and Echo about the practical benefits to be derived in the coming years from our space program in the fields of weather forecasting and world-wide communications that I am not going to go into detail about this phase of our program.

I think the most significant indicator of the shape of things to come is the tremendous interest which a great variety of industries are showing in the field of satellite communications. AT&T recently made a presentation to the Federal Communications Commission in support of their request that appropriate radio frequency channels be reserved for space communications in which they stated their conviction that satellite communications systems would provide a more economical means than new submarine cables for meeting the greatly increased demands for trans-oceanic telephone services during the coming decade.

We can be sure that these practical benefits from our space program will be forthcoming -- and much sooner than almost anyone anticipated two or three years ago.

## Manned Space Flight

This brings us to the third category in our program which is concerned with the travel of man into space, at first in orbital flight about the earth for short periods, later in flights to the moon, and still later to the planets and outer reaches of the solar system. As you know, we are already deeply engaged in Project Mercury, which is designed to put a manned satellite into orbit about 120 miles above the earth's surface, let it circle the earth three times in the space of four-and-a-half hours, and then bring it back safely. The goal of Project Mercury is to determine the degree to which man can tolerate the environmental conditions of space flight and still perform operations sufficiently important to warrant his participation in future space explorations, with all the additional complexity his presence imposes.

Project Mercury, we believe, is an essential step before we can proceed with other, more difficult manned space missions. All of our plans for the scientific exploration of space assume that eventually man will participate in that exploration. The trouble is that, although all of us think men can be useful in this new environment, we don't know for sure.

If it should turn out that men cannot perform useful work in space, it may be that the direction of a substantial portion of our efforts will have to be changed. Project Mercury is the simplest way to learn what we need to know about man's capabilities in space at the earliest possible date.

The accomplishment of Project Mercury will mark a tremendous step forward in extending the frontiers of flight. The speed of flight will be increased by a factor of eight over present achievements, and the altitude by a factor of five. The environment encountered in space flight will be one that man has never approached before. This has required major technical advancements in many fields, including aerodynamics, biotechnology, instrumentation, communications, attitude control, environmental control, and parachute development -- to mention only a few.

By its very advanced nature, Project Mercury has opened the door for the next step in the manned space flight program, which we have named "Project Apollo." This next step involves the development and construction of an advanced manned spacecraft with sufficient flexibility to be capable of both circumlunar flight and useful earth-orbital missions during the present decade. In the long range, this spacecraft should lead toward manned landings on the moon and planets, and toward a permanent manned space station.

To sum up, here are some of the highlights of NASA's 10-year plan as we look ahead.

1. In 1961, we hope to achieve the first orbital flight of an Astronaut in Project Mercury. We also expect to make the first launching of a spacecraft which will impact the moon.

2. In 1962, we have set the target date for the first launching of an instrumented probe to the vicinity of Venus or Mars, or possibly both.

3. In 1963 or 1964, we propose to make the first

launching of an unmanned vehicle for controlled landing on the moon and the first launching of an orbiting astronomical observatory.

4. In 1964, we hope to launch the first unmanned vehicle intended to circumnavigate the moon and return to earth, and to attempt the first reconnaissance of Mars or Venus by an unmanned vehicle.

5. In 1965, the first flight test of a nuclear upper-stage rocket will be accomplished if unexpected problems are not encountered.

6. In the 1965 to 1967 time period, we are planning the first launching in a program leading to manned circumlunar flight and to a near-earth space station.

7. And finally, we expect to accomplish manned flight to a landing on the moon and return to earth some time beyond 1970, the end of the period covered by the 10-year plan.

During the next decade, 62 launchings are expected to be required for the development of new and more powerful launch vehicles; 41 for missions relating to manned space flight; 96 for scientific satellites; 33 for lunar and planetary missions; and 28 for practical applications of satellites. This is at a rate which exceeds two major launchings per month in the total program for the next 10 years as we now see it.

I think we can derive much satisfaction from the solid accomplishments of the past two years. The box score looks pretty good. But more important is the long-term program in which we are now engaged. Our present deficiency in the weight lifting capacity of launch vehicles will, we hope, soon be remedied. I want to reiterate most emphatically that this present deficiency in no way indicates that U.S. science and technology are inferior to that of the Soviet Union. It is simply the direct result of decisions made several years ago in connection with the development of ballistic missiles for our defense.

Our long-range program is designed to achieve the goals of space exploration with the greatest speed consistent with sound scientific and technical management. While we are not engaged in an event-by-event space race with the Soviet Union, we do have a program that we are confident will achieve for the United States a preeminent position in this new business of space exploration.